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SHARP PC-1500 POCKET COMPUTER SOLUTIONS TO STATISTICAL  
DATA ANALYSIS OF C... (U) UNIVERSAL ENERGY SYSTEMS INC  
DAYTON OH W J PARK OCT 83 AFWAL-TR-83-4096

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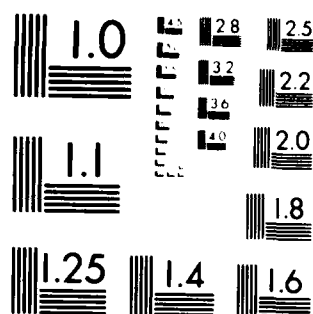
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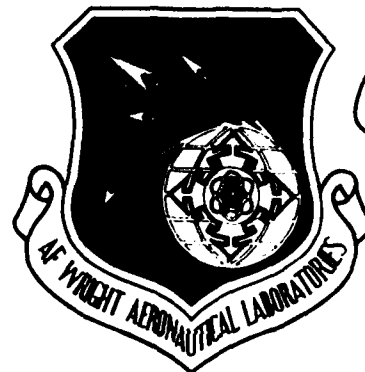
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AFWAL-TR-83-4096



SHARP PC-1500 POCKET COMPUTER SOLUTIONS TO STATISTICAL DATA  
ANALYSIS OF COMPOSITE MATERIALS OR METALS

WON J. Park  
Universal Energy Systems, Inc.  
Dayton, OH 45432

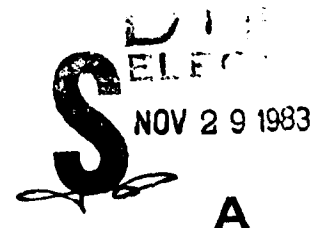
Final Report for period June 1983 - October 1983

October 1983

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AIR FORCE WRIGHT AERONAUTICAL LABORATORIES  
AIR FORCE SYSTEMS COMMAND  
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433



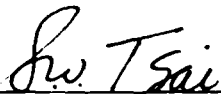
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This technical report has been reviewed and is approved for publication.



STEPHEN W. TSAI, Chief  
Mechanics and Surface Interactions Branch  
Nonmetallic Materials Division

FOR THE COMMANDER



FRANKLIN D. CHERRY, Chief  
Nonmetallic Materials Division

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18. SUPPLEMENTARY NOTES These Programs use the language of BASIC and with additional 8KB RAM memories. The computer software contained in this report is theoretical and/or references and in no way reflect Air Force-owned or developed computer software.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) BASIC Programming Weibull distribution A&B - Allowables Estimations S-N Curve (Linear regression)		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This volume contains the description and instructions of the use of Sharp PC- 1500 Pocket Computer for statistical data analysis, in Weibull failure dis- tribution setting, of the strength or fatigue life of composite materials or metals. Instant calculations in maximum likelihood estimates, A and B allowables, S-N curve (linear regression) and prediction can be made for practical use. ←		

## FOREWORD

This report was prepared in the Mechanics and Surface Interactions Branch (AFWAL/MLBM), Nonmetallic Materials Division, Materials Laboratory, Air Force Wright Aeronautical Laboratories, Wright-Patterson AFB, Ohio. The work was performed under Contract F33615-82-C-5001; SB5448-82-C-0076.

The time period covered by this report was from June to October 1983. Dr. Won J. Park was a senior scientist from Universal Energy Systems, Inc. and Professor of Mathematics and Statistics at Wright State University.

Those who want to receive the programmed magnetic cassette tape should contact Stephen W. Tsai, AFWAL/MLBM, Wright-Patterson AFB, Dayton, Ohio 45433, Tel: 513-255-3068.



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## TABLE OF CONTENTS

<u>SECTION</u>		<u>PAGE</u>
I	USER GENERAL INSTRUCTIONS. . . . .	1
II	CONTENTS OF PROGRAMS . . . . .	2
III	DESCRIPTION OF STATISTICAL METHODS . . . . .	3
IV	PROGRAM DESCRIPTION. . . . .	7
	(A) Flow Diagram . . . . .	7
	(B) Key Operation Procedure. . . . .	8
	(C) Memory Contents. . . . .	13
	(D) Sample Programs. . . . .	15
	(E) Program Listing. . . . .	18
V	CONCLUSION. . . . .	21
	REFERENCES	

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SECTION I  
USER GENERAL INSTRUCTIONS

- (1) The program language for PC-1500 Pocket Computer is BASIC and the elementary part of BASIC program instructions are given in the SHARP Instruction manual, which comes with PC-1500 Pocket Computer.
- (2) The 8 K RAM should be attached to the computer to increase its capacity. Printer is also required to attach the computer.
- (3) The program is called "STAT". This program name is used to load or save the program into cassette tape recorder.
- (4) The programs are started in mode RUN by instruction RUN (press the keys [R] [U] [N] and [ENTER] ). User is guided through the programs by simple questions. The user types the chosen answer and presses the key [ENTER].
- (5) The program is recorded on magnetic cassette tape. To load the program from the cassette recorder to the computer, press [C] [L] [O] [A] [D] ["] [S] [T] [A] [T] ["] and [ENTER].
- (6) The STAT-program contains mainly two sub programs, characterized by the computations of (i) Single-level data and (ii) Multi-level data.
- (7) For single-level data, the maximum number of data points which can be input is 48 and for multi-level data, it is the same at each level. The capacity for the stress levels input is 7.
- (8) The input data value has to be positive number. Otherwise the computation is resulted in error, indicating that an illogical calculation has been made.
- (9) The Weibull parameters are estimated by the maximum likelihood method.



SECTION II  
CONTENTS OF PROGRAMS

- (A) Computation of Single-Level Data:
  - (1) Data input
  - (2) Mean and standard deviation
  - (3) Weibull parameter estimations
  - (4) Confidence interval and A & B allowables
  - (5) Plot of Weibull failure distribution
- (B) Computation of Multi-Level Data:
  - (1) Data input
  - (2) Weibull parameter estimation (pooled)
  - (3) Plot of failure distributions
  - (4) S-N curve (Linear regression)

### SECTION III

#### DESCRIPTION OF STATISTICAL METHODS

##### (A) Single-Level Data

(1) It is assumed that the failure data  $X_1, X_2, \dots, X_n$  of sample size  $n$  were generated from a Weibull distribution with parameters  $\alpha$  and  $\beta$ , that is, its cumulative distribution function is expressed as

$$F(x) = 1 - \exp \left[ - \left( \frac{x}{\beta} \right)^\alpha \right], \quad x > 0.$$

This data may be obtained from ultimate strength tests or fatigue test of composite materials or metals. Note that  $\alpha$  and  $\beta$  are called the shape and scale parameters respectively.

(2) The mean and standard deviation are computed simply by

$$\text{mean } \bar{x} = \Sigma x$$

$$\text{standard deviation } s = \left[ \frac{\Sigma x^2 - (\Sigma x)^2/n}{n-1} \right]^{1/2}.$$

(3) Weibull parameter estimates are obtained by the maximum likelihood method; the scale parameter estimate  $\hat{\alpha}$  is the solution of the following M.L. equation (See [3]):

$$\frac{\Sigma x^{\hat{\alpha}} \ln x}{\Sigma x^{\hat{\alpha}}} - \frac{1}{\hat{\alpha}} - \frac{\Sigma \ln x}{n} = 0$$

The solution is calculated by using the newton's approximation method.

The scale parameter  $\beta$  is estimated by

$$\hat{\beta} = \left[ \frac{1}{n} \sum x^{\hat{\alpha}} \right]^{1/\hat{\alpha}}$$

(4) Confidence interval for  $\beta$  and A & B allowables are obtained from the following formulas:

$$95\% \text{ C.I. for } \beta = \hat{\beta} \exp \left[ -\ell_{.95} / \hat{\alpha} \right]$$

where  $\hat{\alpha}, \hat{\beta}$  are M.L.E. of  $\alpha$  and  $\beta$

and  $\ell_{.95}$  = Critical values given in [3],

$$A - \text{allowable} = \beta^* \left[ \ln (1/.99) \right]^{1/\hat{\alpha}}$$

$$B - \text{allowable} = \beta^* \left[ \ln (1/.90) \right]^{1/\hat{\alpha}}$$

where  $\beta^* = 95\% \text{ C.I. for } \beta$ .

(5) Note that if a random variable  $X$  has a Weibull distribution with parameter  $\alpha$  and  $\beta$ , then its log transformation  $T = \ln X$  has the extreme value distribution with parameters  $a = 1/\alpha$  and  $b = \ln \beta$ ; i.e. the cumulative distribution of  $T$  is

$$F(t) = 1 - \exp \left[ - \exp \left( \frac{t - b}{a} \right) \right].$$

The graphing of cumulative failure distribution is performed under (i) without the log transformation or (ii) with the log transformation. The sample data points are plotted using the median rank  $p_j = (j-.3)/(n+.4)$ .

(B) Mult-Level Data

(1) Under fatigue stress level  $S_i$ ,  $i=1,2,\dots,m$ , the fatigue life cycles  $X_{i1}, X_{i2}, \dots, X_{in_i}$  are observed from the life test, which is theoretically generated from the Weibull distribution with parameters  $\alpha$  and  $\beta_i$ . It is also assumed that the shape parameter  $\alpha$  is the same for all stress levels.

(2) Weibull parameters are again estimated by the M.L. method. The common shape parameter  $\alpha$  is estimated by solving the M.L. equation (See [2]):

$$\sum_i \left[ \frac{\sum_j \hat{\alpha} X_{ij} \ln X_{ij}}{\sum_j \hat{\alpha} X_{ij}} \right] - \frac{m}{\hat{\alpha}} - \sum_i \left[ \frac{\sum_j \ln X_{ij}}{n_i} \right] = 0$$

The scale parameter  $\beta_i$  (under stress levels  $S_i$ ) is obtained from

$$\hat{\beta}_i = \left[ \frac{1}{n_i} \sum_j X_{ij}^{\hat{\alpha}} \right]^{1/\hat{\alpha}}, \quad i=1,2,\dots,m$$

(3) The plotting of failure distribution curve is performed exactly the same way as illustrated in (A)-(5). Here only the log transform of the data is used as data points in the plotting.

(4) S-N curve fitting (linear regression) is carried out under the assumption of Weibull regression model (See [1]). The linear equation to fit is

$$(a) \quad Y_i = \ln \hat{\beta}_i = a + b \ln S_i \text{ (classical S-N curve) or}$$

$$(b) \quad Y_i = \ln \hat{\beta}_i = a + b \cdot S_i.$$

The case (b) may be applied to the rupture testing data.

Because of various sample size  $n_i$  of different stress level, we have to use the weighted least square method (See [4]).

The regression parameters  $a$  and  $b$  are to estimated minimizing

$$Q = \sum_{i=1}^m \frac{(Y_i - \hat{Y}_i)^2}{W_i} \quad \text{where } \hat{Y}_i = \hat{a} + \hat{b} \ln S_i \text{ and } W_i = 1/n_i.$$

The following formulas are used in our computations:

$$\text{RSS} = \text{residual sum of square} = \sum_{i=1}^m \frac{(Y_i - \hat{Y}_i)^2}{W_i}$$

$$\text{RMS} = \text{residual mean square} = \text{RSS}/(m-2)$$

$$\text{SS}_y = \text{total variation of } y = \sum_{i=1}^m \frac{(Y_i - \bar{Y})^2}{W_i}$$

where  $\bar{Y}$  = mean of data  $Y_i$

$$\text{correlation coefficient} = \left[ 1 - \text{RSS}/\text{SS}_y \right]^{1/2}$$

$$\text{SS}_{\text{reg}} = \text{Sum of square for regression} = \text{SS}_y - \text{RSS}$$

$$\text{F-score for regression} = (m-2) \text{SS}_{\text{reg}}/\text{RSS}.$$

which has F-distribution with (1,  $m-2$ ) degree of freedoms.

For a new stress level  $S$ , the prediction of  $\beta$  is computed

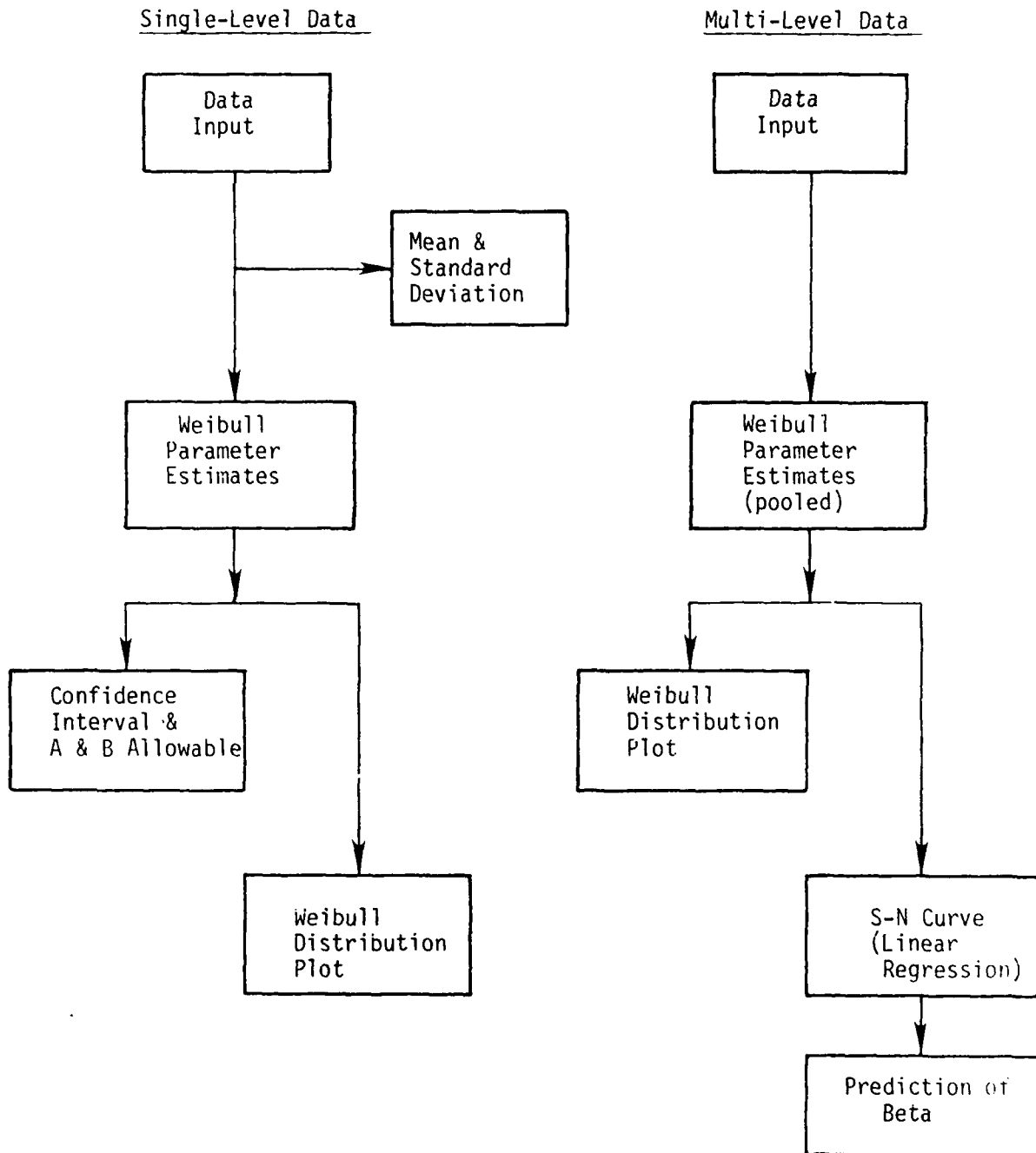
$$\beta \text{ (predicted)} = \exp (\hat{a} + \hat{b} \ln S) \quad (\text{Case (a)}).$$

or

$$\beta \text{ (predicted)} = \exp (\hat{a} + \hat{b} S) \quad (\text{Case (b)}).$$

SECTION IV  
PROGRAM DESCRIPTION

(A) Flow Diagram:



(B) Key Operation Procedure:

Following data are used to illustrate the key operations.

(i) Single-Level Data: T300/934 (0/45/90/-45)<sub>s</sub>

Ultimate Tensile Strength in MPa

402	430	443	457	466	473	478
484	489	496	503	509	518	

(ii) Multi-Level Data: T300/934 (0/45/90/-45)<sub>s</sub>

Tension-Tension Fatigue at 3 Levels

1. At level 1 of maximum stress 290 MPa

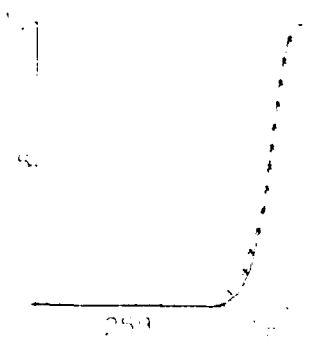
1 872 851	2 359 300
1 437 800	1 698 100
215 984	864 420

2. At level 2 of maximum stress 345 MPa

87 373	60 912	51 260
11 491	81 571	69 711
59 320	51 848	54 187

3. At level 3 of maximum stress 400 MPa


1 664	7 954	690
1 643	6 430	100
5 705	8 430	1 121
5 329	7 232	5 347

DISPLAY	INPUT	PRINT OUT & REMARKS
MULTI-LEVEL DATA ? (Y/N)	RUN [ENTER]	SINGLE-LEVEL DATA INPUT DATA N= 13 402.00 430.00 443.00 452.00 466.00 473.00 478.00 484.00 489.00 496.00 503.00 509.00 518.00
HOW MANY DATA N = ?	N [ENTER]	
DATA - 1	13 [ENTER]	
?	402 [ENTER]	
DATA - 2	430 [ENTER]	
?	.	
.	.	
.	.	
DATA - 13	518 [ENTER]	
?		
MEAN & ST. DEV. ? (Y/N)	Y [ENTER]	MEAN= 472.32 ST. DEV. = 33.11
WEIBULL PARAMETER ESTIMATE		ALPHA= 18.782 BETA= 4.8202E 01
A,B-ALLOWABLE ? (Y/N)	Y [ENTER]	95% C. I. FOR BETA= 473.11 A-ALLOWABLE = 320.34 B-ALLOWABLE = 410.00
WEIBULL PLOT ? (Y/N)	Y [ENTER]	
LOG TRANS. OF DATA ? (Y/N)	N [ENTER]	



DISPLAY	INPUT	PRINT OUT & REMARKS
MULTI-LEVEL DATA ? (Y/N)	Y [ENTER]	
NUMBER OF LEVELS =	3 [ENTER]	MULTI-LEVEL DATA
AT LEVEL - 1		NO. OF LEVELS = 3
NO. OF DATA =	6 [ENTER]	LEVEL WITH LARGEST FATIGUE CYCLE IS LEVEL-1
DATA IN CYCLES		
DATA - 1		NO. OF DATA = 6
?	1872851 [ENTER]	1872851
DATA - 2		1437800
?	1437800 [ENTER]	215984
.		2359300
.		1698100
.		864420
DATA - 6	864420 [ENTER]	STR. LEVEL = 290.0
?		NO. OF DATA = 9
APPLIED STRESS LEVEL =	290 [ENTER]	82323
AT LEVEL - 2		11491
NO. OF DATA =	9 [ENTER]	59320
DATA - 1	87373 [ENTER]	60917
?		81521
DATA - 2	11491 [ENTER]	51848
?		51260
.		69211
.		54182
.		STR. LEVEL = 345.0
DATA - 9	54187 [ENTER]	NO. OF DATA = 12
?		1664
		1643
		5205
		5329
		2954
		6430
		8430
		2232
		690
		100
		1121
		5342
		STR. LEVEL = 400.0

DISPLAY	INPUT	PRINT OUT & REMARKS
APPLIED STRESS LEVEL	345 [ENTER]	
AT LEVEL - 3		
NO. OF DATA =	12 [ENTER]	
DATA - 1	1664 [ENTER]	
?		
DATA - 2	1643 [ENTER]	
?		
.	.	
.	.	
.	.	
DATA - 12	5437 [ENTER]	
?		
APPLIED STRESS LEVEL	400 [ENTER]	

DISPLAY	INPUT	PRINT OUT & REMARKS
WEIBULL PARAMETER ESTIMATE		POOLED ALPHA=1.815 BETA-1= 1.5423E 06 BETA-2= 6.1611E 04 BETA-3= 5.0738E 03
WEIBULL PLOT ? (Y/N)	Y [ENTER]	 LOG(CYCLE)
S-N (BETA) CURVE ? (Y/N)	Y [ENTER]	REGRESSIN LINE 1: $\log N = a + b * \log S$ (N=BETA)  RES. MEAN SQUARE = 1.8520E-01  CORR. COEFF. = 0.939  F-SCORE FOR REGR. 1360.14 DEG. OF FREEDOM (1, 1)  b (SLOPE) = -12.21 a (INTERCEPT) 1.1461E 01  STR. LEVEL= 252.0 BETA PREDICTED= 2.0180E 02
LOG TRANS OF S ? (Y/N)	Y [ENTER]	
SELECT STRESS LEVEL =	250 [ENTER]	
MORE STRESS LEVEL ? (Y/N)	N [ENTER]	

(C) Memory Contents:

MEMORY	DESCRIPTION	MEMORY	DESCRIPTION
(Memory in General)		(Single level data)	
B	Index variable	N	Sample size
C	No. of levels	T	Mean
I	Index variable	S	Standard deviation
J	Index variable	H	95% C.I. for Beta
K	Control variable	P	A - allowable
Z	Control variable	Q	B - allowable
D\$	Control variable	B(I)	Table values from [3]
G\$	Control variable	(Weibull	parameter estimation)
L\$	Control variable	R	$\sum X^\alpha \ln X$
C(I)	$n_i$ = sample size of ith level	S	$\sum X^\alpha$
D(I)	$S_i$ = stress level	T	$\sum \ln X$
X(J)	x - coordinate	U	$\sum X^\alpha (\ln X)^2$
Y(J)	y - coordinate	V	$\sum \left[ \frac{\sum \ln X}{n_i} \right]$

† expressed in term of memories

\* hear X = failure data

MEMORY	DESCRIPTION	MEMORY	DESCRIPTION
$G^+$	$W + C/A/A$	L	$\sum n_i \beta_i S_i$
A	Shape parameter $\alpha$	M	$\sum n_i \beta_i^2$
B(I)	Scale parameter $\beta_i$	G	$K*T - I*I$
Weibull plot		D	Intercept a
N	Sample size	F	Slope b
Z(j)	Data	E	Residual Sum of Square
W	Width of graph	V	Residual Mean Square
E	Plotting Interval in x-coordinate	R	Correlation Coefficient
S	Scale Inticator	S	F-score for regression
T	Scale Inticator	L	New Stress Level
(S-N Curve)		Y	Beta Predicted
T	$\sum n_i$	O	$\sum \left[ \frac{\sum X^\alpha \ln X}{\sum X^\alpha} \right]$
P	$\sum \beta_i, \bar{\beta}$	$W^+$	$\sum \left[ U/S - (R/S)^2 \right]$
Q	$\sum n_i (\beta_i - \bar{\beta})^2$	$F^+$	$O - C/A - V$
I	$\sum n_i S_i$		
J	$\sum n_i \beta_i$		
K	$\sum n_i S_i^2$		

+ expressed in term of memories

(D) Sample Programs:

1. T300/934 [0/±45/90]<sub>s</sub>, Ultimate Tensile Strength in MPa and Tension-Tension Fatigue Test Data.

SINGE-LEVEL DATA

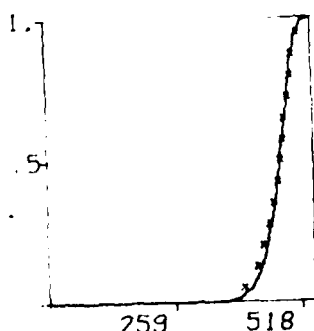
INPUT DATA N= 13

402.00  
430.00  
443.00  
457.00  
466.00  
473.00  
478.00  
484.00  
489.00  
496.00  
503.00  
509.00  
518.00

MEAN= 472.92  
ST. DEV.= 33.22

ALPHA= 18.782  
BETA= 4.8702E 02

95% C.I. FOR BETA=  
473.11  
A-ALLOWABLE =  
370.34  
B-ALLOWABLE =  
419.69



MULTI-LEVEL DATA

NO. OF LEVELS = 3

LEVEL WITH LARGEST  
FATIGUE CYCLE IS  
LEVEL-1

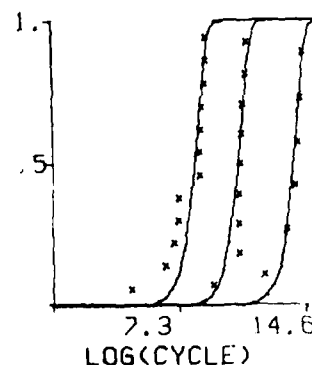
NO. OF DATA = 6  
1872851  
1437800  
215984  
2359300  
1698100  
864420

STR. LEVEL= 290.0

NO. OF DATA = 9  
873/3  
11491  
59320  
60912  
81571  
51848  
51260  
69711  
54187  
STR. LEVEL= 345.0

NO. OF DATA = 12  
1664  
1643  
5705  
5329  
7954  
6430  
8430  
7232  
690  
100  
1121  
5347  
STR. LEVEL= 400.0

POOLED ALPHA=1.815  
BETA-1= 1.5473E 06  
BETA-2= 6.1615E 04  
BETA-3= 5.0738E 03



REGRESSIN LINE IS  
 $\log N = a + b * \log S$   
(N=BETA)

RES. MEAN SQUARE =  
1.0570E-01

COR. COEFF. = 0.999

F-SCORE FOR REGR. =  
1360.13  
DEG. OF FREEDOM=  
(1, 1)

b (SLOPE) =  
-17.71  
a (INTERCEPT) =  
1.1460E 02

STR. LEVEL= 250.0  
BETA PREDICTED=  
2.0180E 07

2. T300/934 [0/±45/90]<sub>s</sub>, Static Tension Strength in MPa and Tension- Tension Fatigue Test Data

SINGE-LEVEL DATA

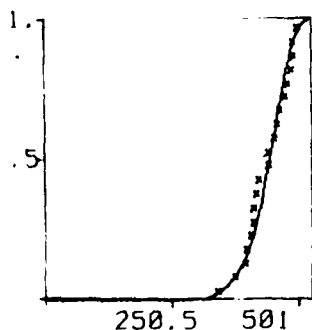
INPUT DATA N= 20

345.00  
376.00  
501.00  
398.00  
399.00  
494.00  
407.00  
412.00  
494.00  
492.00  
412.00  
418.00  
482.00  
478.00  
425.00  
444.00  
465.00  
462.00  
444.00  
456.00

MEAN= 440.20  
ST. DEV.= 44.00

ALPHA= 12.313  
BETA= 4.5926E 02

95% C.I FOR BETA= 443.82  
A-ALLOWABLE = 305.47  
B-ALLOWABLE = 369.69



MULTI-LEVEL DATA

NO.OF LEVELS = 6

LEVEL WITH LARGEST  
FATIGUE CYCLE IS  
LEVEL-1

NO.OF DATA = 3  
2876800  
1698100  
864420  
STR. LEVEL= 42.0

NO.OF DATA = 3  
279440  
351900  
564720  
STR. LEVEL= 46.0

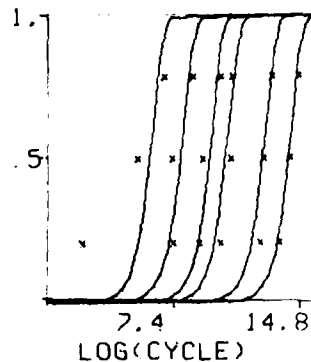
NO.OF DATA = 3  
26764  
58530  
51260  
STR. LEVEL= 50.0

NO.OF DATA = 3  
9888  
7798  
30520  
STR. LEVEL= 54.0

NO.OF DATA = 3  
5705  
1643  
1664  
STR. LEVEL= 58.0

NO.OF DATA = 3  
8  
229  
1079  
STR. LEVEL= 62.0

POOLED ALPHA=1.591  
BETA-1= 1.9226E 06  
BETA-2= 4.0931E 05  
BETA-3= 4.6744E 04  
BETA-4= 1.7874E 04  
BETA-5= 3.3384E 03  
BETA-6= 5.6960E 02



REGRESSIN LINE IS  
 $\log N = a + b * \log S$   
(N=BETA)

RES. MEAN SQUARE = 2.5099E-01

COR. COEFF. = 0.996

F-SCORE FOR REGR. = 534.91  
DEG. OF FREEDOM = (1, 4)

b (SLOPE) = -20.54  
a (INTERCEPT) = 9.1403E 01

STR. LEVEL= 38.0  
BETA PREDICTED= 1.7252E 07

STR. LEVEL= 34.0  
BETA PREDICTED= 1.6956E 08

### 3. T/300/934, $[0_2/+45_2/90_2]_S$ , Tension-Tension Fatigue Test Data

#### SINGE LEVEL DATA

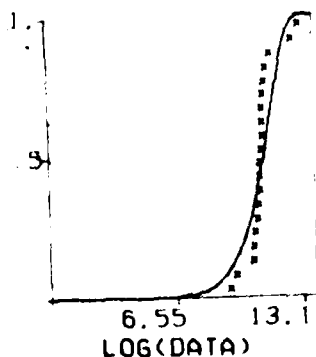
INPUT DATA N= 20

11491.00  
17578.00  
40270.00  
41200.00  
44830.00  
51848.00  
54187.00  
58530.00  
59320.00  
60912.00  
64070.00  
69711.00  
70049.00  
70497.00  
71400.00  
81571.00  
87373.00  
116667.00  
367644.00  
512600.00

MEAN= 92587.40  
ST. DEV. 121686.04

ALPHA= 1.071  
BETA= 1.0086E 05

95% C.I FOR BETA=  
68085.68  
A-ALLOWABLE =  
928.74  
B ALLOWABLE =  
8329.71



#### MULTI-LEVEL DATA

NO.OF LEVELS = 2

LEVEL WITH LARGEST  
FATIGUE CYCLE IS  
LEVEL-1

NO.OF DATA = 20

11491  
17578  
40270  
41200  
44830  
51848  
54187  
58530  
59320  
60912  
64070  
69711  
70049  
70497  
71400  
81571  
87373  
116667  
367644  
512600

STR. LEVEL= 50.0

NO.OF DATA = 20

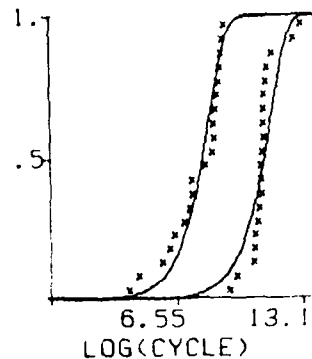
61  
100  
359  
528  
690  
1121  
1588  
1643  
1664  
3558  
4930  
7329  
7417  
5405  
6430  
7232  
7954  
8430  
9060  
9590  
58.0

STR. LEVEL=

POOLED ALPHA=1.035

BETA-1= 9.9195E 04

BETA-2= 4.1177E 03



REGRESSIN LINE IS  
 $\log N = a + b * \log S$   
(N=BETA)

b (SLOPE) =  
-2.1437E 01  
a (INTERCEPT) =  
9.5369E 01

STR. LEVEL= 42.0  
BETA PREDICTED=  
4.1664E 06

STR. LEVEL= 34.0  
BETA PREDICTED=  
3.8642E 08



(E) Program Listing:

```

1: "STAT".TEXT :
  COLOR 0
10: DIM X(50), Y(50)
    , Z(50), A(7, 50)
    , B(50), C(7), D
    (7)
15: INPUT "MULTI-LEVEL DATA ? (Y/N)"; G$
20: IF G$="Y" GOTO 600
25: LPRINT "SINGLE-LEVEL DATA": LF (1)
28: GOSUB 1190
30: INPUT "HOW MANY DATA N=?"; C(1)
35: LPRINT "INPUT DATA N="; C(1): LF (1)
45: C=1, K=1, Z=1
50: FOR J=1 TO C(1)
60: PAUSE "DATA "+STR$(J)+" =": INPUT A(1, J)
65: GOSUB 1200
70: LPRINT A(1, J): NEXT J
150: INPUT "MEAN & ST.DEV. ? (Y/N)"; G$: IF G$="N" GOTO 700
155: N=C(1): LF (1)
170: T=0, S=0: FOR J=1 TO N
174: T=T+A(1, J), S=S+A(1, J)*A(1, J)
176: NEXT J
178: S=S-T*T/N
180: T=T/N, S=S/(N-1)
182: S=JS
183: GOSUB 1200
184: LPRINT "MEAN="; T
186: LPRINT "ST.DEV.="; S: LF (1)
200: GOTO 700
321: IF K>1 GOTO 351
325: GRAPH : COLOR 1
330: GLCURSOR (25, -240): SORGN
335: LINE (-5, 0)- (190, 0), 0, 1
337: LINE (190, 0)- (190, 200), 0, 1
338: LINE (190, 200)- (0, 200), 0, 1
340: LINE (0, 200)- (0, -5), 0, 1
345: W=180/Z(N)
346: LINE (90, 0)- (90, -5), 0, 1
347: LINE (180, 0)- (180, -5), 0, 1
348: LINE (0, 100)- (5, 100), 0, 1
349: LINE (0, 200)- (-5, 200), 0, 1
351: FOR J=1 TO N
352: LET Y(J)=(J-.3)/(N+.4): NEXT J
360: FOR J=1 TO N
362: X(J)=Z(J)*W
364: Y(J)=Y(J)*200: NEXT J
370: FOR J=1 TO N
375: LINE (X(J)-2, Y(J)-2)- (X(J)+2, Y(J)+2), 0, 1
376: LINE (X(J)-2, Y(J)+2)- (X(J)+2, Y(J)-2), 0, 1: NEXT J
385: IF K>1 GOTO 400
390: E=Z(N)/40
400: IF D$="N" GOTO 480
415: FOR J=0 TO 42
420: X(J)=E*J
430: Y(J)=1-EXP (-EXP ((X(J)-LN B(1))*A))
440: X(J)=X(J)*W, Y(J)=Y(J)*200
450: NEXT J: GOTO 490
480: FOR J=0 TO 42
485: X(J)=E*J
486: Y(J)=1-EXP (-X(J)/B(1)*A)
487: X(J)=X(J)*W, Y(J)=Y(J)*200: NEXT J
490: FOR J=1 TO 42
492: LINE (X(J-1), Y(J-1))- (X(J), Y(J)), 0, 1: NEXT J
496: IF Z=2 AND K=1 GOTO 555
497: IF K=CGOTO 500
498: IF K>1 GOTO 555
500: GLCURSOR (-25, 195)
510: LPRINT "1."
520: GLCURSOR (-25, 95)
530: LPRINT ".5"
540: GLCURSOR (50, -20)
545: S=INT (E*400)
550: S=S/10
551: T=S/2
552: LPRINT STR$(T)
553: GLCURSOR (140, -20)
554: LPRINT STR$(S)
555: RETURN
558: LF (2)
560: INPUT "A, B-ALLOWABLE ? (Y/N)"; G$
562: IF G$="N" GOTO 900
564: GOSUB 1250
565: GOSUB 1200
566: H=B(1)*EXP (-B(N)/A)
567: LPRINT "95% C.I. FOR BETA=", H
568: P=H*((LN (1/.99))^((1/A)))
570: Q=H*((LN (1/.9))^((1/A)))
575: LPRINT "A-ALLOWABLE = ", P
580: LPRINT "B-ALLOWABLE = ", Q
590: GOTO 900
600: Z=2: LF (2)
601: LPRINT "MULTI-LEVEL DATA"
602: LF (1)
603: INPUT "NUMBER OF LEVELS ="; C

```

```

605:GOSUB 1190
606:LPRINT "NO.OF
      LEVELS =";C:LF
      (1)
608:LPRINT "LEVEL
      WITH LARGEST F
      ATIGUE CYCLE I
      S      LEVEL-1
      ":LF (1)
610:FOR I=1TO C
615:PAUSE "AT LEVE
      L-"+STR$ (1)
620:INPUT "NO.OF D
      ATA =";C(1)
624:GOSUB 1190
625:LPRINT "NO.OF
      DATA =";C(1)
627:IF I>1GOTO 630
628:PAUSE "      DATA
      IN CYCLES"
630:FOR J=1TO C(1)
640:PAUSE "DATA-"+
      STR$ (J):INPUT
      A(I,J)
645:GOSUB 1210
650:LPRINT A(I,J):
      NEXT J
663:GOSUB 1197
665:INPUT "APPLIED
      STRESS LEVEL=
      ";D(1)
675:LPRINT "STR. L
      EVEL=";D(1):LF
      (1)
690:NEXT I
700:A=2:BEEP 2
705:PAUSE "WEIBULL
      PARAMETER EST
      IMATES"
710:U=0,W=0,O=0
720:FOR I=1TO C
725:R=0,S=0,T=0,U=
      0
730:FOR J=1TO C(1)
740:R=R+(A(I,J)^A)
      *LN A(I,J)
750:S=S+A(I,J)^A
760:T=T+LN A(I,J)
770:U=U+(A(I,J)^A)
      *LN A(I,J)*LN
      A(I,J)
775:NEXT J
805:W=W+(U/S-(R/S)
      ^2),U=U+T/C(1)
810:O=O+(R/S):NEXT
      I
825:F=O-C/A-U,G=W+
      C/(A*A)

```

```

830:IF ABS (F/G)<.
      01GOTO 847
845:A=A-F/G:GOTO 7
      10
847:GOSUB 1185
849:IF Z=1GOTO 852
850:LPRINT "POOLED
      ALPHA=":LF (-
      1)
851:LPRINT A:GOTO
      853
852:LPRINT "ALPHA=
      ";A
853:FOR I=1TO C
855:B(1)=0:NEXT I
860:FOR I=1TO C
863:FOR J=1TO C(1)
865:B(1)=B(1)+(A(I
      ,J)^A):NEXT J
866:B(1)=(B(1)/C(1
      ))^(1/A)
868:GOSUB 1170
870:IF Z=1GOTO 872
871:LPRINT "BETA-
      "+STR$ (1)+"=";
      B(1):GOTO 875
872:LPRINT "BETA="
      ;B(1)
874:IF Z=1GOTO 558
875:NEXT I:LF (1)
900:INPUT "WEIBULL
      PLOT ? (Y/N)"
      ;G$:IF G$="N"
      GOTO 1300
901:IF Z=2LET D$="
      Y":GOTO 904
902:INPUT "LOG TRA
      NS.OF DATA ? (
      Y/N)";D$
904:FOR I=1TO C
905:N=C(1),K=1
906:FOR J=1TO N
907:Z(J)=A(I,J):
      NEXT J
909:IF D$="Y"GOSUB
      1260
910:GOSUB 1005
928:GOSUB 321
940:NEXT I
945:COLOR 0:TEXT
950:LF (1)
955:IF D$="N"GOTO
      965
960:IF Z=2GOTO 962
961:LPRINT "      L
      OG(DATA)":GOTO
      965
962:LPRINT "      LO
      G(CYCLE)"
965:IF Z=1GOTO 15

```

```

970:LF (2):GOTO 13
      00
1000:Z(J)=Z(H),Z(
      H)=M:RETURN
1005:FOR J=2TO N
1110:AREAD Z(J)
1120:FOR H=1TO J-
      1
1130:IF Z(J)<Z(H)
      LET M=Z(J).
      GOSUB 1000
1135:NEXT H
1160:NEXT J:
      RETURN
1170:USING "#.###
      #^":RETURN
1185:USING "###.#
      ##":RETURN
1190:USING "####".
      RETURN
1197:USING "#####
      #":RETURN
1200:USING "#####
      ##.##":
      RETURN
1210:USING "#####
      ###":RETURN
1250:B(5)=.1.107,B
      (6)=.939,B(7
      )=.829,B(8)=
      .751,B(9)=.6
      91,B(10)=.64
      4,B(11)=.605
1251:B(12)=.572,B
      (13)=.544,B(
      14)=.520,B(1
      5)=.499,B(16
      )=.48,B(17)=
      .463,B(18)=.
      447
1252:B(19)=.433,B
      (20)=.421,B(
      21)=.409,B(2
      2)=.398,B(23
      )=.388,B(24)
      =.379,B(25)=
      .37
1253:B(26)=.362,B
      (27)=.354,B(
      28)=.347,B(2
      9)=.34,B(30)
      =.334,B(31)=
      .328,B(32)=.
      323

```

```

1254: B(33)=.317, B
      (34)=.312, B(
      35)=.307, B(3
      6)=.302, B(37
      )=.297, B(38)
      =.293
1255: B(39)=.289, B
      (40)=.285, B(
      41)=.281, B(4
      2)=.278, B(43
      )=.274, B(44)
      =.271
1256: B(45)=.267, B
      (46)=.264, B(
      47)=.261, B(4
      8)=.258, B(49
      )=.255, B(50)
      =.253: RETURN
1260: FOR J=1 TO N
1262: Z(J)=LN Z(J)
      : NEXT J
1265: RETURN
1300: IF Z=1 GOTO 1
      5
1302: INPUT "S-N(B
      ETA) CURVE ?
      (Y/N)"; L$
1303: IF L$="N"
      GOTO 15
1305: INPUT "LOG T
      RANS. OF S ?
      (Y/N)"; S$
1306: IF S$="N"
      GOTO 1308
1307: LPRINT "REGR
      ESSIN LINE I
      S logN= a +
      b * logS
      (N=BETA)":
      GOTO 1310
1308: LPRINT "REGR
      ESSIN LINE I
      S logN = a +
      b * S
      (N=BETA)"
1310: T=0, P=0: LF (
      1)
1312: FOR B=1 TO C
1315: IF S$="N"
      GOTO 1320
1317: X(B)=LN D(B)
      : GOTO 1324
1320: X(B)=D(B)
1324: Z(B)=LN (B(B
      ))
1326: T=T+C(B): P=P
      +Z(B): NEXT B

1328: I=0: J=0: K=0:
      L=0: M=0: Q=0
1330: P=P/C
1332: FOR B=1 TO C
1335: Q=Q+(Z(B)-P)
      *(Z(B)-P)*C(
      B)
1340: I=I+C(B)*X(B
      ): J=J+Z(B)*C
      (B)
1350: K=K+X(B)*X(B
      )*C(B): L=L+X
      (B)*Z(B)*C(B
      )
1360: M=M+Z(B)*Z(B
      )*C(B): NEXT
      B: LF (1)
1410: G=K*T-I*I
1420: D=(J*K-I*L)/
      G
1430: F=(T*L-I*J)/
      G
1440: E=0
1450: FOR B=1 TO C
1460: Y(B)=Z(B)-(D
      +F*X(B))
1470: Y(B)=Y(B)*Y(
      B)*C(B)
1480: E=E+Y(B):
      NEXT B
1495: IF C=2 GOTO 1
      540
1500: U=E/(C-2)
1505: GOSUB 1170
1510: LPRINT "RES.
      MEAN SQUARE
      = "; U: LF
      (1)
1520: GOSUB 1185
1522: R=J/(1-E/Q)
1523: LPRINT "COR.
      COEFF.=": R:
      LF (1)
1525: GOSUB 1200
1526: S=(Q-E)/U
1527: LPRINT "F-SC
      ORE FOR REGR
      . = "; S
1530: LPRINT "DEG.
      OF FREEDOM=
      (1,
      "+STR$(C-2)
      +")": LF (1)
1540: LPRINT " b (
      SLOPE) =
      "; F
1543: GOSUB 1170
1545: LPRINT " a (
      INTERCEPT) =
      "; D:
      LF (1)
1560: GOSUB 1197
1570: INPUT "SELET
      STRESS LEVE
      L="; O
1575: LPRINT "STR.
      LEVEL="; O
1577: IF S$="N"
      GOTO 1580
1578: O=LN O
1580: Z=D+F*O
1590: Y=EXP (Z)
1595: GOSUB 1170
1600: LPRINT "BETA
      PREDICTED=
      "; Y
1610: INPUT "MORE
      STRESS LEVEL
      ? (Y/N)"; R$
      : LF (1)
1620: IF R$="Y"
      GOTO 1560
1650: GOTO 15
1700: END

```

## SECTION V

### CONCLUSION

The description and instruction of the use of Sharp PC-1500 Pocket Computer for the key calculation of statistical data analysis, in Weibull distribution, are presented in this paper. Instant calculation of A and B allowables, S-N curve fitting and prediction can be made for practical use.

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**DATE**  
**ILME**